

**An Economic Analysis of Climate Change Effects
on Agricultural Productivity: A Case Study on
Climate Vulnerability of Farmers in Bundelkhand
Region of Uttar Pradesh**

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1.0 The Context

With unique features in the solar system, viz., distance from the sun, period of rotation, more than 70 percent surface area covered by oceans and rest of surface area covered by forest, mountains, grasslands, rivers and deserts, Earth is only known planet in the human knowledge, where life is available in the survival form (IPCC, 2012a, p. 2). However, due to heterogeneity in climatic conditions, Earth's climate is a complex interactive aggregate of physio-chemical and biological systems (Panda A., 2013, p. 1). The climate in a narrow sense is usually defined as "average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years" (IPCC, 2014a, pp. 119-120). The classical period of averaging these variables is 30 years, as defined by the World Meteorological Organisation. The relevant quantities are most often surface variables such as temperature, rainfall and wind speed. Further, climate in a wider sense includes a statistical description of the climate system (IPCC, 2014a, p. 120). On the other hand, climate change refers to a change in the state of the climate that can be identified (using statistical tests) by changes in the mean and/or the variability of its properties and persists for an extended period, typically decades or longer (IPCC, 2014a, p. 120). The difference in temperature is due to a suite of gases called greenhouse gases, which affect the overall energy balance of the Earth's system by absorbing infrared radiation. In its existing state, the Earth-atmosphere system balances absorption of solar radiation by the emission of infrared radiation to space. Due to greenhouse gases, the atmosphere absorbs more infrared energy that it re-radiates to space, resulting in a net warming of the Earth-atmosphere system and of surface temperature. This is the "Natural Greenhouse Effect". Thus, natural greenhouse effect makes life possible on the Earth by maintaining the required temperature¹ (IPCC, 2014a p. 124). However, it is observed that global concentration of greenhouse gases (carbon dioxide, methane, nitrous oxide and fluorinated gases) has rapidly increased in the atmosphere since pre-industrial era as a result of mainly anthropogenic activities (IPCC, 2014a, p. 120).

¹ Climate varies naturally on all time-scales from hundreds of millions of years down to the year-to-year. Prominent in the Earth's history have been the 100,000 years glacial-interglacial cycles when climate was mostly cooler than at present. Global surface temperature have typically varied by 5°C to 7°C through these cycles, with large changes in ice volume and sea level, and temperature changes as great as 10°C to 15°C in some middle and high latitude regions of the Northern Hemisphere.

Humans are in the center of the undesirable changes in the Earth system. Their past and current unsustainable economic actions are mainly responsible. The undesirable changes are more profound and increase the degree of sensitivity with less adaptive capability. Anthropogenic greenhouse gases released into the atmosphere remains more than 100 years if we stop adding greenhouse gases to the atmosphere today. Ecological economists argue that sustainable use of natural resources keep in mind availability for the future generation and carrying capacity of the earth will help in human footprint reduction. Rockstrom et al. (2009, p.3) proposed the concept of “Planetary Boundaries approach²”. This is the synonyms of “Safe Minimum Standard”.³ Both planetary boundaries and safe minimum standard concepts argued that the use of natural resource should be below from the threshold level. Rockstrom et al. (2009, p. 4) identified important Earth- system processes and their associated thresholds, if crossed, could generate unacceptable environmental change. They found nine such processes to define planetary boundaries viz., climate change, the rate of biodiversity loss (terrestrial, land and marine), interference with nitrogen and phosphorus cycles, stratospheric ozone depletion, ocean acidification, global freshwater use, change in land use, chemical pollution and atmospheric aerosol loading. The planetary boundaries approach rests on three branches of scientific enquiry. The first addresses the scale of human action in relation to the capacity of the Earth to sustain it, a significant feature of the ecological economics research agenda, drawing on work on the essential role of the expansion of the economic subsystem (Boulding, 1966, pp. 125-130). The second is the work on understanding essential Earth- system processes, including human actions brought together in the evolution of global change research towards Earth-system science and in the development of sustainability science. The lastly, framework of resilience and its links to complex dynamics and self-regulation of living systems, emphasizing multiple basins of attraction and threshold effects.

Furthermore, by used large-scale data, a group of scientist found that four of nine planetary boundaries have now been crossed as a result of anthropogenic activity. The four are: climate change, loss of biosphere integrity, land-system change and

² The idea that there is an identifiable set of boundaries, beyond which anthropogenic change will put the Earth system outside a safe operating space for humanity, is attracting interest in the scientific community and gaining support in the environmental policy world.

³ The Safe Minimum Standard (SMS) approach is a collective choice process that prescribes protecting a minimum level of a renewable natural resource unless the social costs of doing so are somehow excessive or intolerably high.

altered biogeochemical cycles (phosphorus and nitrogen (Steffen et al., 2015, pp. 1-15). They proposed that concentration of carbon dioxide in the atmosphere should not exceed 350 parts per million above from pre- industrial era, which they were observed 387 parts per million. Similarly, the rate of biodiversity loss in terms of species extinction rate (number of species per million species per year) is currently more than 100 in comparison to the proposed boundary of 10 numbers of species per million per year. Interference with the nitrogen cycle, the study argued that the amount of reactive nitrogen has already pushed into land, ocean, and atmospheric systems from the carrying capacity of the earth. Local level to regional- scale of anthropogenic interference with the nitrogen cycle and phosphorus flows have induced an abrupt shift in lakes and marine ecosystems (Rockstrom et al., 2009, p. 2). It is argued by the authors that transgressing these boundaries will increase the risk of irreversible climate change, viz., loss of ice sheets, sea level rise, shifts in forest, and importantly agricultural system.

Agriculture in the developing countries like India provides employment for the more than half of the unskilled population. Macro agricultural statistics such as net sown area and average land size is either skewed or decline. On the other hand, consumption of fertiliser, area under irrigation, use of hybrid seeds, use of pesticides have increased over the decades. In other words, Indian agriculture after implementation of green revolution becomes resource intensive, less profitable for small and marginal farmers, which are nearly 85 percent of total land holders in recent years. Further, small and marginal farmers in the absence of sufficient non- farm employment are highly vulnerable, less productive and remain unemployed in the off cropping season. The total food grains production statistics show a surplus in quantities and sufficient to feed domestic demand. On the other hand, minor cereals, pulses and some non- food grain crop productivity has still very much lower and imported from rest of the world to feed domestic demand. It increases the domestic prices and leads to higher food inflation. Furthermore, apart from the important agricultural determinants, viz., irrigated area, consumption of chemical fertilisers, pesticides, seeds, and technology used in agriculture, the role of environmental factors, viz., rainfall, temperature, solar radiation, wind speed, and concentration of carbon dioxide in the atmosphere etc. are vital and crucial for agricultural productivity. It is observed that variability in climatic factors such as rainfall and temperature has been increased over the last five decades. In India,

where the majority of farm practices depend on Monsoon rainfall, it becomes highly variable and unpredictable due to rise in mean surface temperature and concentration of greenhouse gases especially carbon dioxide in the atmosphere. These environmental factors adversely affect the current farm- practices.

Therefore, the issue is that the current farm practices with lower socio-economic and biophysical conditions are not able to cope with current abrupt climate change, which is not only a major global environmental problem but also an issue of great concern to the developing countries like India. More specifically, current research work addressed four key issues in the Indian agriculture, i.e., resource intensive, adversely affect the climate change, highly vulnerable farmers, and lower adaptive capabilities. IPCC (2014d, p. 124) in the fifth assessment report (working group I, II, III) observed that farm practices in the developing countries are highly unsustainable. Farmers are using artificial sub-additives in the unsustainable manners. It declines farm productivity and increased the cost per hectare. Farmers are still living bottom of the line in the complex social system with nominal basic amenities. Given the lack of resources and access to technology and finance, the developing countries such as India have limited capacity to develop adaptive capacities to reduce their degree of vulnerability to change in climate.

1.1 Climate Change Impacts on Indian Agriculture

With heterogeneous agro-climatic conditions, lower fertility, decline mean land size, higher reliance on farming, decline in investment, increase in greenhouse gases concentration, increase in temperatures and increase in rainfall variability, Indian agriculture is potentially affected in the recent years. Further, least adoption of modern technology in the marginal and small farmers has increased the degree of vulnerability. Therefore, in the Indian agriculture context, studies are broadly classified in three groups, viz., potential impact, vulnerability assessment, and adaptation assessment.

The first group of studies are assessed the potential impact of climatic factors, viz., rainfall, temperatures and greenhouse gases on farm productivity. Goswami et al. (2006, pp. 245-250) observed that intensity of climate-related events during 1950-2000 has increased. In India, agriculture still depends on monsoon rainfall pattern which is now less predictable and more intense. Rainy days are declined on one hand and on the other hand, the intensity of heavy and heavier rainfall events has increased. Monsoon

pattern is changing towards early Rabi cropping season (post monsoon period). This change adversely affects both two major cropping seasons, viz., Kharif and Rabi. They argued that the agricultural situation is more critical in two ways. First, more than 60 percent of cropped area are under rainfed conditions, which means monsoon rainfall is not sufficiently available to maintain the current cropping pattern. Second, in the absence of water for irrigation, unregulated bore wells are responsible for desertification. Farmers are over- utilising water for irrigation, which leads to water shortage in the lean season.

The second group of studies assessed vulnerability in the India agriculture. Aggarwal et al (2002, p. 32) argued that Southern and Western India, compared to northern and eastern regions, are likely to show a greater sensitivity and vulnerability to climate change. Districts concentrated in Rajasthan, Madhya Pradesh, Gujarat, as well as southern Bihar and western Maharashtra are highly vulnerable to globalisation and climate change is likely to pose simultaneous challenges to the agricultural sector. Low vulnerability areas lie in the Indo-Gangatic Plains. Further, their regional analysis, Brenkert and Malone (2005, p. 21) assessed the climate- induced vulnerability in I Indian states using the Vulnerability- Resilience Indicator Prototype (VRIP). Results show nine Indian states to be moderately resilient to climate change, principally because of low sulphur emission and a relatively large percentage of unmanaged land. Further, six states are more vulnerable than India as a whole, attributable largely to sensitivity to sea storm surges. They found that most vulnerable states are six coastal states in India are most vulnerable with high population density⁴. The small mountainous northern inland states show the highest resilience among the India States. Orissa and Tamil Nadu show high sensitivity to sea- storm surges.

The third group of studies assessed adaptation strategies at a farm level. Coping with climate change, farmers started different autonomous adaptation strategies. Crop rotation, less water consuming crops, short- duration crops, improved irrigation facilities, use of hybrid seed, and insurance are key adaptation strategies applied at a farm level. Pandey R. and Shashidhar K. Jha (2008, pp. 487- 506) observed that farmers are using indigenous varieties of seeds, shifting cropping pattern and delay sowing period. But the exposure of the adverse impact of climate change has increased in the

⁴ Sensitivity indicator results show that six coastal states, viz., Goa, West Bengal, Tamil Nadu, Kerala, Orissa and Gujarat.

unpredictable manners. On the other hand, the cropped area sown by using indigenous varieties of seeds is much lower. In majority, large as well as small and marginal farmers are using hybrid varieties of seeds without testing soil requirements and, it leads to lower farm productivity.

1.2 Research Gap

An extensive literature review has done by assessing agricultural situation, impact of climate change on crop productivity, farmer's life and current adaptation strategies to deal with climate change in India. It is identified that in India, majority of studies (Kumar et al. 2015a, pp. 12-16 and Gupta S et al. 2012, pp. 1-10) estimated climate change impact on crops productivity by using state level data. Only BIRTHAL et al. (2014, p. 145-155) used district level panel data compiled by ICRISAT. However, BIRTHAL et al. (2015, p. 12) have used data between 1970 to 2001, 200 district and nine crops of both kharif and rabi season crops. The present study has added more district 291 of 16 states and 15 crops. Further, it is identified that in Bundelkhand region part of Uttar Pradesh, no such type study has earlier conducted to examine agro, social, economic and demographic impact of climate change. Therefore, present study fill this gap by assessing climate and livelihood vulnerability. Further, the present study also examines current adaptation strategies follows by the farmers to reduce the degree of climate vulnerability.

1.3 Objectives of the Study

Based on the extensive review of literature and existing gaps identified in the field of agriculture situation, potential climate change impact, vulnerability and adaptation to climate change, the objectives of the present study are as follow.

1. To examine growth, extent and dimensions of Indian Agriculture after implementation of Green Revolution technology.
2. To estimate the climate change impact on Indian Agriculture.
3. To examine climate and livelihood vulnerability among the farmers in Bundelkhand region of Uttar Pradesh.
4. To examine adaptation methods for preventing the impact of climate change on agriculture productivity in Bundelkhand region of Uttar Pradesh.

5. To suggest policy measures to enable Farm Households to cope with Climate Vagaries.

1.4 Hypothesis of the Study

1. Green Revolution brought disparities in the cropping pattern and resource use.
2. Climate change adversely affected to the crop productivity in India.
3. Climate Change increases the degree of vulnerability among the Surveyed Farmers.
4. Current coping strategies in agriculture are not able to cope with climate change.

1.5 Methodology

(A) Data & Study Area

Both secondary and primary data have been collected to assess the objectives of the study. Secondary data on agriculture statistics, viz., net sown area, gross sown area, net irrigated area, and total fertiliser consumption, number of tractors, land holding size and environmental parameters, viz., annual rainfall, minimum & maximum temperature are collected during 1966 to 2011 from the ICRISAT database, IMD database, India water portal meta database, Indian fertilisers association and Ministry of Agriculture and Farmers Welfare, Government of India. The present study estimated climate change impact on crop productivity by using district level agricultural and environmental statistics during 1966 to 2011 in India. For the crop productivity estimation, sixteen major food grains producing states are selected, viz., Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. Further, 291 districts of these states are included in the climate change impact estimation.

The field level study also conducted in the most agriculture, the socio-economic backward region in India viz., Bundelkhand region. Bundelkhand region comprises in the two states and thirteen districts. Seven districts belong to the Uttar Pradesh and six districts are belongs to the Madhya Pradesh. In the Bundelkhand region, the bulk of economic activities takes place in the primary sector. Besides, economic underdevelopment, the region is also prone to the frequent disaster like droughts.

Further, Bundelkhand has a hot and semi-humid climate. The average annual temperature is over 25°C. However, the mean monthly values vary considerably from the annual means and consequently, the temperature range is high. In summer mean temperatures range around 30°C and can rise beyond 43°C in May - June. The monsoon from June to September bring down temperatures to around 22°C- 25°C with relative humidity varying between 70 to 80 percent. The mean annual precipitation varies from 75 C.M. in the north to 125 C.M. in the south-east. The average for the region can be considered around 100 cm and falls mainly in the monsoon months of June to September.

(B) Sampling Method and Size

Based on the agro, socio-economic profile of the seven districts, two districts are identified for the field survey, viz., Jhansi and Jalaun. Jhansi district is developed among the seven districts of Bundelkhand region part of Uttar Pradesh. The coverage of the canal network is higher. The soil quality and education level of rural population, connectivity to headquarter through a road network also higher. On the other hand, the characteristics, viz., agro, social, economic, demographic of Jalaun district are similar to other districts and lower compare to Jhansi. Therefore, Jalaun district is selected as under developed district. From both two districts, 100-100 samples are collected. Within districts, all Tehshils are covered (both two districts have five- five Tehshils). Further, from each Tehshil, one block is selected and within block one village selected for the household identification. Furthermore, within selected village, 20 samples are collected by considering social categories characteristics. Total, 200 samples from the ten villages are collected. Further, primary data collected on the socio-economic conditions of the sample households, farm productivity, access to agricultural credit, basic amenities, income and expenditure, cropping pattern, adaptation and coping strategies to drought and climate change and barriers to adaptation.

(C) Statistical Techniques and Model

The current study used five tier estimation methods, viz., descriptive statistics, semi-log model, multiple regression analysis, indicator approach and binary logistic regression.

1. Descriptive Statistics

Descriptive statistics are used to describe the basic feature of the data. They provide simple summaries about the sample and measures. Together with simple graphics analysis, they form the basis of virtually every quantitative analysis of data. In the present study mean, standard deviation, correlation is used to make data presentable.

2. Semi-log Model

The compound annual growth rate of the cropped area and production in the periods, viz., 1966-90 and 1991-2011 is estimate by using semi-log model as follows.

$$\ln Y_t = \beta_1 + \beta_2 T + U_t \dots \dots \dots (6)$$

where, $\ln Y_t$ is log of dependent variable, i.e., area & production of the crop, β_1 is constant, β_2 is time and U_t error term.

3. Fixed Effect Feasible Generalized Least Square Model

An estimation of climate change impact on crop productivity, fixed effect feasible generalized least square model is used. The regression model assumes that aggregate production for each time- period depends on upon irrigated area, sown area, rainfall, minimum & maximum temperature in sowing, germination & harvesting period, rural literates, fertiliser consumption, number of tractors and number of pump sets. Further, by using regression coefficient values, marginal effect and future impact of rainfall and temperatures on crop productivity in four time periods, 204, 2060, 2080 and 2100 are estimates.

4. Indicator Approach

The examination of degree of vulnerability to climate change at community level, present study adopted an indicator based method and developed, Climate Vulnerability Index (CVI) and Livelihood Vulnerability Index (LVI). Based on which the extent of climate change vulnerability of the 10 villages of the study region has been indexed. CVI is used, where the vulnerability was based on components of exposure, sensitivity and adaptive capacity at the community level. Each component in the framework is composed of several sub-components. Selection of sub-components were based on the

insights gained from the review of literature, indicator that are specific to drought prone regions and adaptation actions among the community farmers. The Iyegar and Sudarshan (1982, p. 12) method has been adopted to calculate and rank the block in terms of vulnerability score.

5. Binary logistic Regression Analysis

The examination of the current adaptation strategies to cope with climate induced vulnerability and potential impacts, binary logistic regression model is used to analyse the factors influence the adaptation strategies in the region.

1.6 Organisation of the Thesis

The thesis consists of seven chapters as follows:

Chapter 1 entitled “Climate Change: Issues and Challenges” consists nine sections. First three sections deal with context, impact of climate change on farm productivity at global level and impact of climate change on the Indian farm productivity. Section four consists four sub-sections. It provides intensive & critical review on the changes in the agricultural situation after adoption to green revolution in 1.3.1, impact of climate change on farm productivity in 1.3.2, climate induced vulnerability in 1.3.3 and the current coping strategies to deal with climate change. Section five discuss the research gap and need of the study. Section six and seven discuss the objective and hypotheses of the study. While section seven explains detailed methodology of the present study.

Chapter 2 entitled “Climate Change and Economic Development: Perspectives and Approaches” provides the background on the theoretical scope of the study. It consists two sections. The first section discussed the debate on economic development and environmental degradation. The debate started the classical literature that economists view on growth in the absence of efficient management of natural resources. Over utilization of natural resources leads to environmental negative externalities. The ecological economists view on the sustainability environment only possible solution to deal with adverse climate change. Second section discusses the development of the climate change methods for capturing the impact on farm productivity.

Chapter 3 entitled “Agriculture Development in India: State Level Analysis” consists six sections. First section discusses the current position in the India economy. Second section discusses the estimation methods for examination of crop growth during 1966-

2011. Section three and four discusses in the change in cropping pattern and land use pattern. Section four discusses the performance of the Indian agriculture. Further, section five discusses the change in the major agricultural production determinants. It includes various determinants, viz., economic, technological, institutional and environmental. Section six provides major findings and conclusion.

Chapter 4 entitled “Impact of Climate Change on Agricultural Productivity in India” consists nine sections. First two sections deal with introduction and approaches for estimation of climate change impact. Section three, four and five deal with estimation method, formulation of final method and hypothesis testing. Section six discusses the regression results. Section seven and eight show marginal impact on the crops productivity during 1966-2011 and future impact of climate change on the studied crop by the 2100.

Chapter 5 entitled “Assessment of Climate Vulnerability at Community Level” explores the factors, which are responsible for higher vulnerability. It consists six sections. First three sections deal with introduction about vulnerability, approaches and measurement of the climate induced vulnerability at community level. Section four provides socio-economic and agronomic conditions of the surveyed households. Section five and six shows the degree of climate & livelihood vulnerability indexes at community level. Lastly, section six provides conclusion.

Chapter 6 entitled “Assessment of Adaptation Strategies at Household Level” consists thirteen sections. First five sections deal with introduction, adaptive capacity and adaptation, autonomous and planned adaptations and adaptation in the agriculture. Section six shows the current adaptation option followed by the studies households. Section seven, eight, and nine examined the relation between operational land holding size, nature of household & education level and adaptation options. Further, section ten, eleven and twelve deal & examined the probability of adoption of the various adaptation strategies. Lastly, section thirteen provides conclusion.

Chapter 7 entitled “Summary and Conclusion” finally makes some concluding remarks and policy implication which may be useful to reduce present climate change impact on both crop productivity and farmers life.

1.7 Summary and Conclusion of the Study

The chapter one entitled “**Climate Change: Issues and Challenges**” explores the impact of climate change on farm productivity and livelihoods of farmers. Based on the existing review of literature. Some important observations are as follows.

First, farming in the high latitudes that are cooler than the optimum temperature, warming would cause net revenues to go up. On the other hand, farming in low latitudes that are warmer than the temperatures, warming would cause net revenues to fall. These results imply that countries that happen to be in relatively cool regions of the world are likely to get benefit from the warming, those countries that happen to be in relatively warm regions of the world are likely to be harmed by warming.

Second, higher dependency on south-west monsoon in one hand and on the other hand, variability in rainfall pattern and shift towards the post monsoon period is increasing the degree of vulnerability in the Kharif season across the agro-climatic zones in India.

Third, it is found that to cope with climate change, farmers started differential adaptation strategies, viz., crop rotation, less water consuming crops, short-duration crops, improved irrigation facilities, use of hybrid seeds and crop insurance in the Bundelkhand region part of Uttar Pradesh.

Therefore, agriculture needs special attention. Because agriculture provides employment to the majority of rural population, provides raw material and support secondary sector, i.e., growth in industrial sector, provides foods to the 120 hundred million people.

The chapter two entitled “**Climate Change and Economic Development: Perspectives and Approaches**” address the debate on environment versus economic growth as well as development of approaches for measuring the impacts of climate change on agriculture.

First, Malthus and followers argued that with scarce natural resources and the exponential growth in population, we cannot achieve economic growth indefinitely. Further Malthusian was suggested two solutions, viz., preventive and positive checks. The preventive checks consist of voluntary limitations of population growth. On the other hand, the positive check to population is to a direct consequence of the lack of a preventive check. In other words, when society does not limit population growth

voluntarily, diseases, famines and wars reduce population size and establish the necessary balance with resources.

Second, however, neoclassical economists in majority believed that there is no such kind of resource depletion as pointed by the Malthusian economists. Instead, the real issue of significance is to understand the circumstances under which technological progress would continue to ameliorate resource scarcity.

Third, in contrast to neoclassical economists, ecological economists believed that the human economy is a subsystem of the ecosystems. Limits to economic growth could no longer be argued solely on the basis of the possibility of running out of conventional resources as Malthusian believed. Further, technology could not be viewed as the ultimate means of circumventing ecological limits as neoclassical economists advocated.

Fourth, the sustainability economists in the ecological prospective argued that uncertainty about the future changes in ecology is core issue. The problem is not that changes will occur, but rather that we do not know for sure how and when these changes will occur and we do not know what the implications of these changes will be on future resource availability.

Fifth, there is continuous development in the methodology to capture the impact of climate change starting from structural modelling approach to panel data approach, which provide advantages to the future researchers to capture real time impact of climate change on farm productivity as well as livelihoods of the farmers.

Therefore, it is important to understand the externalities occur due to over exploitation of natural resources. The views on limits to economic growth and environmental degradation clearly states that inclusive and sustainable development is the only way to move out from the current tragedy of commons.

The chapter three entitled “**Agriculture Development in India: A State Level Analysis**” made an attempts to examine the performance of Indian agriculture. Further, change in key determinants, viz., economic, technological and environmental during post green revolution and economic reform period are analysed.

First, it is found that forest cover marginally increased about two percent during 1966-2012 at the cost of land not available for cultivation, permanent pasture & grazing land,

land under miscellaneous and culturable waste. Further, the net sown area is purely associated with agricultural practices, shows marginally increased by about 1.22 percent during 1966-2012 respectively. Furthermore an area more than once shows positive outcome of the green revolution. It indicates that area more than once is used for cultivation increased about two percent during 1966-1990 and continuous increased by about six percent during 1991-2012.

Second, the CAGR of gross sown area (GSA) has marginally increased by 0.24 percent annually during 1991-2012, whereas CAGR of net sown area (NSA) shows that it has declined by -0.09 percent annually. Further, with the support of government and well as community participation, the CAGR of net irrigated area (NIA) and gross irrigated area (GIA) increased by 1.26 & 1.55 percent during 1991-2012 respectively. Furthermore, disparities in growth of GSA, NSA, NIA and GIA have found at the state level. NSA has declined in Bihar, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Orissa, Tamil Nadu, Uttar Pradesh, Uttar Pradesh, Madhya Pradesh and West Bengal, whereas, it has increased marginally in Gujarat during 1991-2012. Similarly, GSA has declined in Bihar, Himachal Pradesh, Kerala, Orissa, Tamil Nadu and Madhya Pradesh, whereas it has increased in Gujarat, Haryana, Jammu & Kashmir, Karnataka, Maharashtra, Punjab, Rajasthan, and West Bengal. Furthermore, NIA has increased in all states except Bihar, whereas GIA has increased in all states.

Third, cropping pattern was in favour of food grain crops, especially rice and wheat from post green revolution period to mid-eighties and after words it has changed in favour of non-food grains. Further, regional disparities in the total cropped area for food and non- food grains have found. The cropped area under total food grains has increased in Bihar, Orissa, Punjab, Rajasthan, Uttar Pradesh, West Bengal, Haryana, Jammu & Kashmir and Karnataka, whereas, it declined in Andhra Pradesh, Gujarat, Madhya Pradesh, Tamil Nadu, Kerala and Maharashtra during 1966-2012. Furthermore, the total cropped area under non-food grains has increased in Madhya Pradesh, Rajasthan, West Bengal, Andhra Pradesh, Haryana, Himachal Pradesh, Jammu & Kashmir, Kerala and Maharashtra during 1966-2012.

Fourth, the mean operational land size shows a continuous decline during 1970-71 to 2010-11. It also shows that marginalization has increased rapidly. Marginal farmers were 51 percent in 1970-71 and they are increased by 17 percent, i.e., 67 percent in

2010-11. Further, the operated area has shifted in favour of marginal and large farmers. In 1970-71, 51 percent marginal farmers have owned 9 percent cropped area and it has increased about 22 percent in 2010-11. Furthermore, marginal farmers have increased in the backward states, i.e., Bihar and Uttar Pradesh sharply due to rapid increase in population. In 1995-96, marginal farmers were 80.14 percent and increased by 11 percent in 2010-11. Similarly, the total marginal farmers were 75.42 & 76.42 percent in 1995-96 and it has increased by 79.23 & 82.17 percent in 2010-11 in Uttar Pradesh and West Bengal. The rate of marginalization in the high yield states is lower. Moreover, the regional shift in mean land size also found. Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab and Rajasthan states have higher mean land size, whereas Andhra Pradesh, Bihar, Himachal Pradesh, Jammu & Kashmir, Kerala, Odisha, Tamil Nadu, Uttar Pradesh and West Bengal have lower mean land size.

Fifth, per hectare consumption of chemical fertilisers has increased fourfold during 1991-2012. High yield states such as Andhra Pradesh, Haryana and Punjab have consumed at a higher rate, whereas low yield states, Odisha, Rajasthan, Kerala, Madhya Pradesh and Maharashtra have consumed at a lower rate.

Sixth, there had been imbalance use of nitrogen, potassium and phosphorus fertilisers have found during PGR and EPR. States like, Karnataka, Kerala, Maharashtra, Tamil Nadu, and West Bengal had lower imbalance, whereas, Haryana, Madhya Pradesh, Punjab, Rajasthan and Uttar Pradesh had higher imbalance from the recommended ratio during 1966-2012. Seventh, the higher rate of technological tools adoption, i.e., tractors was observed in all states. It means, the input cost in agricultural labourers has shifted in favour of technological tools, viz., tractors.

Eighth, variability in the environmental factors, viz., rainfall and temperatures was observed during 1966-2012. It is found that rainfall variability has increased in Gujarat, Karnataka, Maharashtra, Orissa, and West Bengal, whereas it has declined in Andhra Pradesh, Bihar, Haryana, Himachal Pradesh, Kerala, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh. Further, maximum temperature was increased in Gujarat, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal, whereas, it was declined in only Andhra Pradesh and Bihar. Furthermore, minimum temperature was increased in Gujarat, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra,

Orissa, and West Bengal, whereas, it was declined in Bihar, Rajasthan and Uttar Pradesh.

Though, green revolution moved out from the food crisis arisen in the early sixties in some extent, yet it brought regional disparities in the resource use, productivity and change in cropping pattern. Promotional price policy for some crops lead to scarcity in others. Change in environmental factors, along with economic and technological factors increased the degree of vulnerability in the farm profits, in particular and the livelihoods of farmers in general.

The fourth chapter “**Impact of Climate Change on Agricultural Productivity in India**” estimates the climate change impact on fifteen major and minor food & non-food grain crops. The calculated marginal effect of rainfall and temperature shows that majority of the crops are potentially affected. Further, increase in temperature up to 1.5⁰C and rainfall up to 7 millimeter would adversely affect by the end of this century to the majority of the crops.

First, rice has the highest mean productivity among the food grain crops, i.e., 3.28 tonnes per hectare, whereas, cotton tops on the list of non- food grains, i.e., 17.50 tonne per hectare. The mean minimum & maximum temperature was 19.54⁰C and 32.07⁰C during 1966-2011 respectively. The annual and monsoon rainfall was 1105.05 and 870.26 millimeter. Further, the number of tractors per thousand hectares was 4.17, whereas the number of pump sets per thousand hectares was 29.49 during 1966-2011. Second, majority of crops are positively associated with non-climatic factors, viz., sown area, rural literates, tractors, fertilisers, irrigated area and number of pump sets except sorghum, pear millet, finger millet, chickpea, pigeon pea, rabi pulses and soybean. These crops are negatively associated with fertilisers.

Third, rainfall in the sowing period negatively associated with yield rice, maize, barley, sorghum, rabi pulses and groundnut, whereas positively associated with yield of wheat, pearl millet, finger millet, chickpea, lime seed, soybean, sugarcane and cotton. Further, rainfall in the germination period negatively associated with yield of wheat, barley, sorghum, pearl millet, pigeon pea, rabi pulses and lime seed, whereas positively associated with the yield of rice, maize, finger millet, chickpea, groundnut, soybean, sugarcane and cotton. Furthermore, rainfall in the harvesting period negatively

associated with the yield of rice, wheat, barley, sorghum, finger millet, chickpea, rabi pulses, groundnut, soybean and cotton.

Fourth, minimum temperature in sowing period is positively associated with the yield of majority crops except from, rice, maize and sugarcane. Further, minimum temperature in the germination period positively associated with the yield of majority crops except for, barley, sorghum, chickpea, pigeon pea, rabi pulses, groundnut and sugarcane. Similarly, minimum temperature in the harvesting period is positively associated with the yield of majority crops except from, wheat, barley, finger millet, groundnut and cotton.

Fifth, maximum temperature in the sowing period is positively associated with the yield of rice, maize, sorghum, raib pulses and soybean, whereas, negatively associated with the yield of wheat, barley, pearl millet, chickpea, sugarcane and cotton. Further, maximum temperature in germination period is positively associated with the yield of wheat, barley, chickpea, pigeon pea, rabi pulses, soybean and cotton, whereas, negatively associated with the yield of rice, maize, finger millet, groundnut and cotton. Furthermore, maximum temperature in the harvesting period positively associated with the yield of wheat, barely, pearl millet, groundnut, lime seed and cotton, whereas, negatively associated with the yield of sorghum, chickpea, pigeon pea, rabi pulses, soybean and cotton.

Sixth, the calculated marginal effect of rainfall, minimum & maximum temperature indicates that in the absence of any adaptation measures, i.e., irrigation, fertilisers and pump sets, etc., the productivity of rice, wheat, barley, sorghum, pearl millet, chickpea, lime seed, soybean, sugarcane and cotton is declined by -6.94, -19.68, -22.81, -86.57, -9.40, -21.47, -2.57, -1.86 & -19.83 percent during 1966-2011.

Seventh, the projected results shows that if the minimum temperature increase up to 1⁰C, maximum temperature increase up to 1.5⁰C and rainfall increase up to 7 millimeter, the productivity of rice, wheat, barley, sorghum, pearl millet, finger millet, chickpea, soybean, sugarcane and cotton would be decline by -13.51, -31.51, -121.20, -36.82, -38.23, -2.26, -1.16 & -17.06 percent by the end of century.

Eighth, the projected results also show that if the minimum temperature increased up to 1.5⁰C, maximum temperature increase up to 4⁰C and rainfall decline up to 20 millimeter, the productivity of rice, wheat, sorghum, pearl millet, finger millet,

chickpea, soybean, sugarcane and cotton would be decline by -56.19, -68.57, -398.58, -103.10, -39.34, -106.05, -35.75, -8.11 & -79.64 percent by the end of century.

Expansion of irrigated area, use of technological factors, viz., chemical fertilisers & pesticides, tractors and pump sets have moderated the degree of adverse impacts of climate change. However, changes in the monsoon rainfall pattern towards the post monsoon period is potentially affecting to the both major cropping seasons, viz., kharif and rabi in India. Further, rise in minimum and maximum temperatures even in the winter season, adding an additional layer of the adverse impacts of climate change. The results show that high yield, higher irrigational crops are at a higher risk rather than low yield crops, viz., kharif pulses and minor cereals.

The fifth chapter “**Assessment of Climatic Vulnerability at Community Level**” develops the livelihood and climate vulnerability indices by using agro, socio-economic conditions of the surveyed households. Education, basic amenities, exposure from the climatic factors, viz., rainfall and temperature, higher dependency on agriculture, lack of non-farm employment opportunities and minimum use of modern technology in the farming have increased the degree of vulnerability among the surveyed households.

First, majority of surveyed households are belong to the Hindu region and headed by male counterparts. Further, more than 60 percent households live in the pucca houses, followed by 19 percent in the semi- pucca houses by using hand pump as a main source of drinking water. Furthermore, 46 percent households are still using open field, followed by 42.50 percent flush and 11.50 dry latrines for the sanitation. Moreover, more than half (56.50 percent) of households are still using non- renewable resources for the cooking purpose and still 27.50 percent households do not have electricity in their house.

Second, heterogeneity in the income distribution is observed among the surveyed households. 29 percent households earns only up to 20 percent income. Another, 11 percent households have an income within the range of 21-40 percent, whereas, next 22 percent households earns within the range of 41-60 percent. Next, 19 percent households earns with the range of 61-80 percent and remaining 19 percent households earns within the range of 81-100 percent. In other words, mean income of nearly 30 percent households is Rs. 41, 224.10, whereas, 11 percent households earned Rs. 66,

545.60 only. Further, 22 percent earns Rs. 97,318.20, whereas, 19 percent earned Rs. 1, 77, 342 and remaining 19 percent earned Rs. 4, 10, 184 annually.

Third, nearly 50 percent individuals are either illiterate or not taken formal education. Further, 22.85 percent individuals have educational qualification up to junior level and only 9.81 & 7.54 percent have taken education up to secondary and senior secondary level. Furthermore, the individuals have the educational qualification up to diploma, graduate and post- graduate only is 0.32, 7.46 & 2.19 percent respectively. This shows that illiteracy and low education level of the surveyed households is high.

Fourth, disparities in the education level on gender basis also significant. The illiteracy rate among females is higher than those of males by 10 percent. Illiterate females and males are 53.14 & 46.86 percent respectively. It is also found that when education is increasing the disparity in the education level also increases among the males and females.

Fifth, there exist positive relation between education level and occupational. It is found that individuals have an education level up to junior, secondary, senior secondary, graduate, diploma and post-graduate, the level of self-employment is 16.67, 24.79, 35.48, 75, 26.09 & 37.04 percent respectively. Majority of individuals belong to illiterate category are agricultural and non-agricultural labour.

Sixth, the agronomic profile of the surveyed households indicates that majority of the farmers belong to the marginal and small operational land size, i.e., 35 & 22.50 percent. Further, the majority of marginal operational households belong to the OBC and SC, i.e., 60 & 26.15 percent respectively. The percentage of small farmers belong to the General, OBC and SC is 35.56, 40 & 24.44 percent. The share of the medium and large farmers among the social categories is lower. It is found that in General category, only 19.61 & 3.92 percent households are medium and large farmers, whereas, in the OBC, only 11.58 & 8.42 percent surveyed households are medium and large farmers.

Seventh, Pahladpur village is highly exposed by the climatic factors, such as increase in temperature, decrease in rainfall and decline in ground water level. Further, Karson village highly sensitive due to dependence on natural resources (90 percent), using hand pump as a main source of drinking water (65 percent), less crop diversification (45 percent), dependency on government sources of irrigation (85 percent), dependency on head of household (65 percent), none using modern health facilities (zero percent), open

defecation (55 percent), only 30 percent households having pucca house and households belong to the below poverty line (30 percent). Furthermore, Biriya village has least adaptive capacity. It is found that only 15 percent households headed by females, 30 percent households have not taken formal education, seven percent solely depends on agriculture, 10 percent have the burden of loan, only 20 percent have changed the cropping pattern, 15 percent have taken information from the Kisan Call Centre (KCC), and 50 percent lives in the joint family structure. The overall livelihood vulnerability index scores show that due to least adaptive capacity, Biriya village has the highest livelihood vulnerability score, i.e., 0.356 respectively.

Eight, the estimated climate vulnerability index shows that Kaithi village (0.925) is highly exposed, Karson village (0.617) is highly sensitive and Karson village (0.350) has the highest adaptive capacity in the Jalaun district. Whereas, Pahladpur village is highly vulnerable by the climate change and variability. Basically, Pahladpur and Kaithi villages have much similar climate vulnerability index scores, i.e., 0.382 & 0.383. However, Pahladpur and Kaithi are high degree of vulnerability. Finally, due to higher exposure, sensitivity and least adaptive capacity, Dunora village is highly vulnerable to the climate change and variability.

Therefore, the livelihood and climate vulnerability profile in the ten villages of two most diversified agricultural districts, i.e., Jalaun and Jhansi depicts that these villages have least crop insurance, least income & crop diversification, higher dependency on head of household, lowest basic amenities and fewer sources of non-farm employment.

The sixth chapter **“Assessment of Adaptation Strategies at Household Level”** examines the different adaptation strategies applied by the farmers to cope with climate change in the Bundelkhand region of Uttar Pradesh.

First, farmers are applying numerous types of adaptation strategies, such as cropping pattern change, switch to non-farm activities, improving irrigation, planting trees in the surrounding of the fields, early maturing varieties of seeds, less water consuming crops, crop diversification and more pesticides and fertilisers. More than 20 percent farmers have changed their cropping pattern, nearly 20 percent switch to non-farm activities, 43 percent improved irrigation, 61 percent planted trees surrounded the fields, 38 percent used maturing varieties of seeds, 43 percent have used less water consuming variety of

crops, nearly 63 percent diversified their cropping pattern and 35 percent increased the consumption of chemical fertilisers and pesticides to cope with climate change.

Second, it is found that in the majority, marginal, small and semi-medium farmers have followed differential adaptation strategies in the surveyed village, whereas medium and large farmers have least adaptation. Karson is only village, where large farmers have the changed cropping pattern (57.14 percent), switch to non- farm activities (71.43 percent), improved irrigation (60 percent), used early maturing varieties of seeds (61.54 percent), less water consuming crops (69.23), crop diversification (53.33), more consumption of fertilisers and pesticides (75 percent).

Third, it is found that exposure from the rainfall and temperature has forced to the highly educated farmers (education qualification above from the secondary level) to change cropping pattern.

Fourth, households living in the joint family structure are inclined to switch non-farm employment activities, because farm income does not sufficient to the livelihood security.

Fifth, households belong to the above poverty line (APL) and insured from the national *Fasal Bima Yojna* have better the coverage of all season irrigation facilities.

Sixth, households belong to the APL category and have educational qualification above from the secondary level more inclined to use an early maturing variety of wheat to moderate adverse impact of climate change.

Seventh, households have better information on continuous increase in temperature over the last five years are more habituated to use less water consuming crop varieties to deals with climate change.

In the light of current adaptation practices, farming in the surveyed villages is highly vulnerable to the climate change. Marginalization in the land size in, decline in rainfall and the increase in temperatures, continuous increase in population, low education level, less access to insurance, modern technology and institutional credit adding an additional layer of the adverse impacts of climate change.

1.8 Policy Recommendations

Some of the recommendations are important to cope with climate change in India as well in Bundelkhand region of Uttar Pradesh.

First, the green revolution has changed the cropping pattern. In the post green revolution period majority of the cropping pattern has been shifted in favour of rice, wheat, sugarcane and cotton at the cost of minor cereals, pulses and some other non-food grain crops. Due to this, surplus production in major cereals and scarcity in pulses and minor cereals have a major reason for the current food crisis. Therefore, there is need of promotion to enhance the share of minor cereals and pulses. Further, pulses are high temperature tolerance and needs fewer resources for the vegetation. In the raifed areas (more than 60 percent cropped area under rainfed conditions in India), it is recommended that pulses are the best option to deal with climate change.

Second, the price support policy has a potential role in the cropping pattern. Therefore, it is recommended that price support policy for the minor cereals and pulses before the sowing period would be helpful. It not only increase the farm- profits, but also reduce resource input cost.

Third, FGLS results confirm that temperature and rainfall are potentially affecting the crop productivity during 1966-2011. Therefore, there is need of temperature tolerance and less water consuming crop varieties to deal with climate change.

Fourth, it is found that information about climate change education has a potential role to moderate the climate change impacts. However, due to illiteracy, farmers are hardly aware about the future climatic conditions, such as rainfall and temperatures. Therefore, agro-climatic zone specific awareness centers nearby villages should be open and farmers to be trained accordingly.

Fifth, it is found that farmers started differential adaptation practices to cope with climate change, such as more fertilisers and pesticides consumption, without knowing the soil requirement. Therefore, it is recommended that creating the soil health card should be compulsory and connected with AADHAR card. So administrator can monitor and recommend best possible solutions. This measure reduces the input cost and leads to farm sustainability.

1.9 Limitations of the Study

There are few limitations of the present study:

First, present study analyses the performance of Indian agriculture during post green revolution period. However, there is a need to present pre-green revolution performance and then compares with post green revolution (PGR) and economic reform period (ERP).

Second, there are three main environmental factors, which are affecting to the crop productivity, viz., rainfall, temperature and carbon dioxide. The present study is only taken rainfall and temperature. The availability of data on CO₂ on temporal and spatial basis is almost nil.

Third, there are seven districts in Bundelkhand region of Uttar Pradesh. The present study has taken only two districts. Therefore, based on the results of various factors in ten village of two districts, are not able to generalise the livelihood and climate vulnerability results.

Fourth, the macro level study at all India level do no cover all districts in all the states during 1966-2011.

1.10 Further Scope of the Study

The present study has not meant to answer all questions those have emerged during the recent research process. However, some of them seem to be worth mentioning in order to be addressed by contemporary studies. There are three stages to analyse the impact of climate change on agriculture sector, i.e., potential impact by using historical data of agricultural determinants including environmental factors, vulnerability impact by either historical data or filed survey data, and adaptation impact using agro, socio-economic datasets. The present study analyses the all three stages by using secondary and primary data with fewer sample size. The present study analyses the potential impact on crop productivity during 1966-2011 and only included 291 districts and fewer determinants of crop productivity. So there is need to increase the time period and also include remaining districts in the future study, so generalization can possible. The present study collected only 200 samples from the two districts out of thirteen districts in Bundelkhand region. Based on this small sample size generalization of

vulnerability and adaptation strategies is not possible. Therefore study can be developed by including more districts with large sample size.